Voxel-wise Comparison of T_1 Relaxation Times and Simultaneously Measured Perfusion and BOLD Signal Increases During Motor Activation

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Purpose

The aim of this study was to compare the spatial distribution and the changes of perfusion and BOLD signals during finger-tapping episodes, together with T_1 relaxation times.

Introduction

Arterial spin labeling (ASL) techniques employ a different physiological principle than BOLD contrast techniques. ASL signal arises mostly from small arteries, capillaries, and brain parenchyma while BOLD signal comes primarily from veins, and tissues and CSF surrounding veins, It is possible that ASL techniques will provide better quantification and localization of the sites of neuronal activity than BOLD techniques. Both ASL and BOLD signals can be simultaneously measured using QUIPSS II with Thin-Slice TI_1 Periodic Saturation [1] that is a modified version of QUIPSS II [2]. With the additional EPI-based T_1 maps obtained in the same sessions, the signal changes due to task activation were correlated to the T_1 values on a voxel-wise basis.

Methods

Studies were performed using a 3T Bruker Biospec 30/60 scanner on five volunteers. PICORE tagging scheme was used with a 10-cm tagged region positioned with 1-cm gap relative to the proximal edge of the imaging slice. Following the inversion tagging pulse, a series of 90° RF pulse, each followed by a gradient crusher, were periodically applied from time TI_1 to TI_{1S} (TI_1 stop time) every 25 ms in a 2-cm periodic saturation slice. The distal edge of the periodic saturation slice was positioned at the distal edge of the tagged region. At time TI_2, images were acquired using gradient-echo EPI. Each volunteer performed bilateral finger-tapping paradigm with 46/69 s on/off cycles, TI_1 = 700 ms, TI_{1S} = 1050 ms, TI_2 = 1400 ms, FOV = 16 cm, slice thickness = 8 mm, matrix size = 64 × 64, TE = 27.2 ms, and TR = 2.3 s. For the purpose of generating a T_1 map for each subject, 24 inversion recovery EPI images were acquired immediately prior to the simultaneous perfusion/BOLD studies with the inversion time increased logrithmically from 30 to 9580 ms and TR = 10 s. To minimize the BOLD weighting in the perfusion data during transitions of task and rest periods, perfusion time series were constructed by subtracting from each image the average of the previous and the next images in the time series. Student's *t* tests were performed for each voxel between activation and baseline images to generate *t*-score images. A ROI was selected for each subject. Relative signal changes of cerebral blood flow (ΔrelCBF) and BOLD (ΔrelBOLD) were calculated in voxels with a probability value of $P < 0.05$ that corresponds to a Bonferroni corrected significant threshold of $P < 1.22 \times 10^{-4}$ for a typical ROI of 410 voxels.

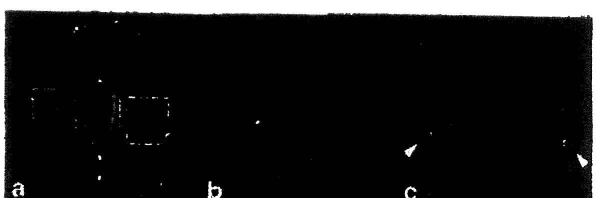

Figure 1. (a) T_1 map with selected ROIs (b) perfusion *t*-score image, and (c) BOLD *t*-score image from one subject.

Results

Figure 1shows the T_1 map and *t*-score images of perfusion and BOLD activation maps from a representative subject. Voxels with large draining veins (arrowheads), which are dark in the T_2*-weighted images due to short T_2* of venous blood at 3T, exhibit significant signal changes in some BOLD activation maps but not in the perfusion activation maps. Figure 2 shows ΔrelCBF *vs.* ΔrelBOLD of the activated voxels in both perfusion and BOLD activation maps. These voxels are divided into Groups A, B, and C, based on the cutoff values of ΔrelCBF = 40% and ΔrelBOLD = 1%. The voxels with T_1 values smaller than 1184 ms (mostly white matter (WM)) are shown in solid triangles, larger than 1870 ms (mostly CSF) in solid squares, and between these two values (mostly gray matter) in open circles. Except in one subject, the T_1 values of the voxels in Group B are significantly different ($P <$ 0.01) from those in the corresponding Group A using Wilcoxon rank-sum test. The T_1 values of the voxels in Group C are significantly different ($P < 0.05$) from those in the corresponding Group A in all subjects.

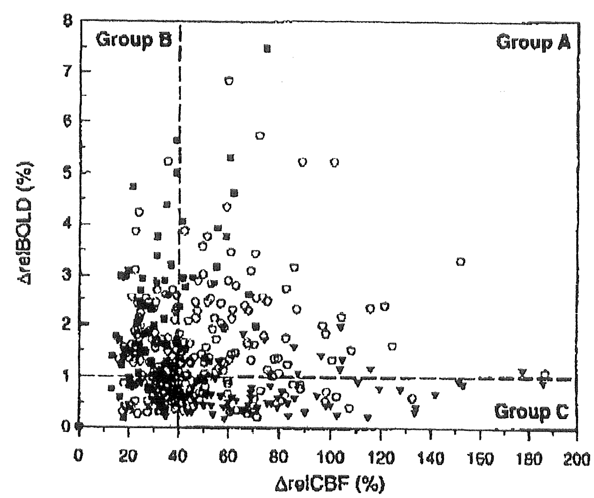

Figure 2. ΔrelCBF *vs.* ΔrelBOLD of the activated voxels (see texts).

Discussion

As expected, WM voxels exhibit low ΔrelBOLD and CSF voxels exhibit low ΔrelCBF. However, some WM voxels show artifactual high ΔrelCBF due to low resting-state perfusion signals while some CSF voxels shows high ΔrelBOLD because of anatomical proximity to pial veins. Large artifactual ASL signals may come from intravascular spins while large BOLD artifactual signals may arise from both intravascular and extravascular components. The overlap of perfusion and BOLD activation maps should represent gray matter surrounding veins and is likely to better represent the sites of neuronal activity than ΔrelCBF or ΔrelBOLD alone. EPI-based T_1 maps provide a mean to segment voxels of similar tissue origins into groups or ROIs , and also provide direct registration to other EPI-based images.

References

1. Luh, W.-M., *et al., MRM* (In press).
2. Wong, E. C., *et al, MRM* 39, 702-708, 1998.
3. Wong, E. C., *et al., NMR Biomed* 10, 237-249, 1997.